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Size and Scale Characteristics of Upper Yukon River Juvenile Chinook Salmon (*Oncorhynchus tschawytscha*)

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SIZE AND SCALE CHARACTERISTICS OF UPPER YUKON RIVER JUVENILE CHINOOK SALMON (ONCORHYNCHUS TSCHAWYTSCHA)

by

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ABSTRACT

Murray, C.B., Henderson, M.A., and Beacham, T.D. 1990. Size and scale characteristics of upper Yukon River juvenile chinook salmon (Oncorhynchus tschawytscha). Can. Tech. Rep. Fish. Aquat. Sci. 1767: 19 p.

Juvenile chinook salmon (Oncorhynchus tschawytscha) were collected from upper Yukon River tributaries in 1987 and 1988. Scale interpretations indicated that the majority of juveniles (92.2%) were in their first summer of life (age 0.0) and their fork length ranged from 47 to 96 mm. The remaining juveniles were in their second summer of life (age 1.0) and their fork length ranged from 65 to 105 mm. Juveniles collected in May 1988 had no identifiable freshwater annulus. If an annulus was forming on the scales of these fish then it was completed sometime after May or it became more distinct with the addition of spring or plus growth during the downstream migration. Variability in fork length among populations of juvenile chinook salmon with the same number of circuli suggested that circuli were not deposited at consistent length increments among populations.

RÉSUMÉ

Murray, C.B., Henderson, M.A., and Beacham, T.D. 1990. Size and scale characteristics of upper Yukon River juvenile chinook salmon (Oncorhynchus tschawytscha). Can. Tech. Rep. Fish. Aquat. Sci. 1767: 19 p.

En 1987 et 1988, des quinnats juvéniles (Oncorhynchus tschawytscha) ont été recueillis dans les eaux tributaires de la partie supérieure du fleuve Yukon. L'étude des écailles montre que la plupart des saumons juvéniles (92,2 %) en étaient à leur premier été (âge 0,0) et leur longueur à la fourche allait de 47 à 96 mm. Les autres en étaient à leur deuxième été (âge 1,0) et leur longueur à la fourche variait de 65 à 105 mm. Chez les quinnats juvéniles recueillis en mai 1988, on ne pouvait déceler aucun anneau de la période de séjour en eau douce. S'il y avait un anneau en formation sur les écailles de ces poissons, il a dû être formé après le mois de mai, ou il est devenu plus visible avec la croissance printannière ou au cours de la migration en aval. Les écarts de taille entre les quinnats juvéniles comptant le même nombre de stries d'accroissement porte à croire que ces dernières se forment pas à des taux de croissance uniformes chez toutes les populations.

INTRODUCTION

Chinook salmon, Oncorhynchus tschawytscha, migrate seaward either during their first spring and summer (ocean-type), or after one or two years in freshwater (stream-type)(Gilbert 1913; Meehan and Siniff 1962; Reimers 1973; Major et al. 1978; Healey 1983). The frequency of stream-type chinook salmon in a spawning population has been positively correlated with the latitude and altitude of the spawning area, with the tendency to remain a year or longer in freshwater determined by the harshness of the rearing environment (Rich 1925).

The Yukon River originates in British Columbia and flows over 3200 km through the Yukon Territory and Alaska to the Bering Sea, draining an area of approximately 860,000 km^2 (Beacham et al. 1989). Chinook salmon in the upper Yukon River mature from 4 to 8 years after egg fertilization and spend at least one (95%) or two winters in freshwater before migrating to the ocean (Gilbert 1922; Healey 1983; Buklis 1987; Beacham et al. 1989). Upper Yukon River chinook salmon spawn from late August to mid-September, with fry emerging from late May to early June (Brown et al. 1976; Walker 1976). Peak smolt out-migrations occur between mid-May and mid-June, with smolts reaching the estuary between June and August (Martin et al. 1987).

Salmonids rearing in severe environments with short growing seasons (glacier fed streams and high alpine lakes) may not develop an annulus on their scale at the end of the first growing season (Brown and Bailey 1952; Hanson and Cordone 1967; Jensen and Johnsen 1982; Lentsch and Griffith 1987). Development of a freshwater annulus on juvenile chinook salmon scales may be dependent upon water temperature during the first year of growth (Tutty and Yole 1978). In this paper we compare circulus counts and size among upper Yukon River populations of juvenile chinook salmon collected in the spring and fall and examine the timing of freshwater annulus formation.

MATERIALS AND METHODS

Juvenile chinook salmon in 15 upper Yukon River tributaries were captured in late August 1987 and between May 26 and August 20 in 1988 (Fig. 1). Fifty minnow traps baited with preserved salmon roe were placed in a variety of habitats (pools, runs, riffles, and cut banks) adjacent to known chinook salmon spawning areas on each tributary (Handcock and Marshall 1984). After 4 hours the traps were checked, fish removed, re-baited, and replaced in the same site for another 4 hours or left overnight.

Empty minnow traps after the first 4 hours were re-baited and moved to a new site. Trapping varied from 8 to 24 hours on each tributary. The distribution and proportion of juvenile chinook salmon sampled in each tributary cannot be calculated due to the minor trapping effort in each tributary. In 1987 we sampled 5 tributaries and in 1988 we resampled 4 of these tributaries plus an additional 10 tributaries not sampled in 1987. In both years the juveniles were anaesthetized and then frozen. We thawed the juveniles in the laboratory and measured fork length to the nearest 1.0 mm with Vernier calipers. Ten scales were removed from the left side of each juvenile approximately two rows above the lateral line along a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (preferred area; Clutter and Whitesel 1956). Scales were mounted on gummed cards and impressions made in acetate plastic cards. Scale samples were not obtained from all fish sampled for fork length.

Scale impressions were magnified 35 times using a photocopying microfiche. Age determinations and circulus counts for each fish were taken from photocopies of non-regenerated scales. Circuli were counted from the scale focus along the longest axis to the outer margin of the scale. An annular ring was identified by the presence of one or more discontinuous circuli between two continuous circuli, circuli crossing other circuli, or two or more closely spaced circuli followed by widely spaced circuli (Lagler 1952). If an annular ring was present, then the number of circuli from the annulus (the last narrowly spaced circuli before the more widely spaced circuli of rapid or spring growth) to the outer edge of the scale was also counted (Ricker 1962, 1964; Bilton and Ludwig 1966). Three independent readers re-aged the scales at 100 times magnification by using projection equipment as described by Ryan and Christe (1976). Ages reported in this paper follow European convention: number of freshwater annuli to the left of the decimal point and number of marine annuli after the decimal point.

Frequency distributions for circulus counts were compared with a likelihood ratio or G-test (Sokal and Rohlf 1981). Variation in fork length of juvenile chinook salmon with the same number of circuli or between age 0.0 and 1.0 fish was analyzed with a one-way analysis of variance model, with tributary or age as the index. Variation in fork length for age 0.0 fish from tributaries sampled in both years was analyzed with the analysis of variance model:

$$Y_{ijk} = \mu + T_i + Y_j + TY_{ij} + e_{ijk}$$

where Y_{ijk} = observed fork length, μ = overall mean, T_i = effect of tributary (i=1,4), Y_j = effect of year (j=1,2), TY_{ij} = interaction between tributary and year, and e_{ijk} = error term for k^{th} observation in subgroup ij.

RESULTS

JUVENILE SIZE AND AGE

The majority of juvenile chinook salmon (92.2%; N = 1153) from upper Yukon River tributaries were age 0.0 and fork length ranged from 47 to 96 mm (Table 1). The remaining juveniles were age 1.0 and fork length ranged from 65 to 105 mm. Age 0.0 and 1.0 fish collected from late May to late August had circulus counts and ranges similar to those illustrated in Fig. 2. As expected, age 0.0 juvenile chinook salmon in August were significantly smaller ($F_{1,1110}$ = 221.7; P<0.01) than age 1.0 juveniles in August.

Fork length for age 0.0 fish differed significantly among tributaries ($F_{3,588}$ = 114.7; P<0.01) and between years ($F_{1,588}$ = 51.7; P<0.01) for chinook salmon sampled from the Nordenskiold River, Tatchun Creek, Bearfeed Creek, and McQuesten River in both years. In both years the pattern of mean juvenile fork length from the longest to the shortest was Nordenskiold River, Tatchun Creek, Bearfeed Creek, and McQuesten River. Juveniles from these tributaries were longer in 1987 than in 1988 probably because of the three weeks difference in sampling dates between the years.

Significant differences in mean fork length were observed among tributaries for juveniles with the same number of circuli (circulus counts ≥ 5) in late August 1987 and (circulus counts ≥ 4) in early August 1988 (all P<0.01). In 1987, juveniles with 6 to 9 circuli from Tatchun and Bearfeed creeks were the longest, those from the Nordenskiold River intermediate, and those from the Nisutlin and McQuesten rivers the shortest. In 1988, juveniles from the Takhini River were the longest and those from the McQuesten River the shortest (Table 1). Circuli were not deposited at consistent length increments among populations and may reflect differences in productivity and juvenile growth rates among tributaries.

CIRCULUS COUNTS

We compared the circulus counts for age 0.0 fish with the circulus counts before the first annulus for age 1.0 fish collected from Blind Creek in August (Fig. 3A). The distribution of circulus counts was similar for both groups of juveniles (G = 2.54; df = 4; P> 0.05). This suggests that very few circuli were added after August and before annulus formation for age 0.0 Blind Creek fish.

The distribution of circulus counts for all age 0.0 juveniles from all tributaries in August had a mean of 6.64 (SE = 0.05; N = 1077) (Fig. 3b). The mean circulus counts for age 0.0 juveniles captured in August 1987 and 1988 were 6.93 (SE = 0.06; N=497) and 6.43 (SE = 0.05; N = 580), respectively. As with mean fork length, mean circulus counts were significantly higher in 1987 than in 1988 ($P < 0.05$) because of the three weeks difference in sampling dates between the two years. If very few circuli are added between August and the time of annulus formation, as suggested by the results from age 0.0 and 1.0 fish sampled from Blind Creek, then the distribution of circulus counts before the first annulus for upper Yukon River chinook salmon would be similar to the one illustrated in Fig. 3b.

SPRING SAMPLING

The eight juveniles aged as 0.0, but that we assume to be age 1.0 because of their large size collected from Bearfeed and Tatchun creeks in May 1988 ranged in fork length from 66 to 96 mm (Table 1). Young-of-the-year chinook salmon, ranging in fork length from 35 to 40 mm, were also collected in Bearfeed and Tatchun creeks in May. The large juveniles captured in May had no indication of an annulus on their scales (3 independent readers) (Fig. 2, scales A and B). The young-of-the-year captured at the same time had no scales. This suggests that an annulus did not form on the scales of some juveniles from Bearfeed and Tatchun creeks during their first year of life or that an annulus was not detectable without spring or plus growth. Scales from Bearfeed Creek juveniles sampled in May (fork length > 60 mm) and August had circulus counts similar to those in Fig. 2 (scales A through D), with a range from 5 to 11 and 3 to 7 circuli, respectively. We compared the total circuli counts for age 0.0 Bearfeed and Tatchun Creek chinook salmon collected in May with the total circuli counts before the first annulus for age 1.0 fish from the Klondike and Mayo rivers and Blind and Wolf creeks collected in August (Fig. 3c). The distribution of circuli counts was similar for both age 0.0 and 1.0 fish ($G = 12.47$; $df = 6$; $P > 0.05$). This suggests that the freshwater annulus may not form on the scales of upper Yukon River chinook salmon until sometime after May of their second year.

DISCUSSION

Scale growth and circuli number roughly parallels the growth of an individual fish (Clutter and Whitesel 1956; Bilton and

Robins 1971) and growth rates have been correlated to the rate of degree-day accumulation (Dwyer et al. 1983). The abundance and spacing of freshwater circuli varies between brood years and among populations of chinook salmon, as indicated by our study, and has been attributed to differences in food availability, temperature, and genotype (Ricker 1972; Reimers 1973; Yole 1989). The survival rate of juvenile chinook and sockeye salmon (Reimers 1973; MacDonald et al. 1987) has been shown to decrease as the size of the juvenile and presumably as the number of circuli decreases.

Reimers (1973) found that there was close agreement between freshwater circulus counts for juvenile and adult chinook salmon from the Sixes River in Oregon. In 1986, age 1.3 and 1.4 chinook salmon returning to the upper Yukon River had a mean of 9.11 and 9.96 circuli, respectively in the first freshwater annular zone (Merritt et.al. 1988). We observed that juvenile chinook salmon rearing in upper Yukon River tributaries in August had a mean of 6.64 circuli in the first freshwater annular zone. The discrepancy in circulus counts between returning adults and juveniles may reflect the addition of circuli after the end of August and before annulus formation, lower survival rates for chinook salmon with low circulus counts in the first freshwater annular zone or warmer water temperatures when the returning adults were juveniles compared with water temperatures in 1987 and 1988 when we collected the juveniles in our study.

Our sampling of the juveniles in the populations may have been size selective owing to our use of minnow traps as sampling gear. However, Brown et al. (1976) using Wolf traps, incline plane traps, and fyke nets found that migrating smolts at the Whitehorse dam had a mean fork length of 93 mm (range 72 to 120 mm). Smolts collected in and near Tatchun Creek between late May and late June by incline plane trap, seine, and fyke net had a mean fork length of 77 mm (range 66-98 mm), 75 mm (range 65-100 mm), and 88 mm (range 68-110 mm), respectively (Walker 1976). Smolts captured by tow net in the Yukon River delta ranged in fork length from 72 to 123 mm between mid-June and early August (Martin et al. 1987). Juvenile chinook salmon seined from the Takhini River in mid-August had a mean fork length of 70 mm, with a range from 56 to 77 mm (Brown et al. 1976). Juvenile chinook salmon collected from the Chena River, Alaska with dip nets and seines ranged in fork length from 34 to 92 mm between early June and late September (Walker 1983). We observed a similar size range (47-105 mm) for juveniles from upper Yukon River tributaries collected by minnow traps. The similarities in size ranges for different gear types suggests that our minnow trap samples are representative of juvenile chinook salmon populations in upper Yukon River tributaries.

All juvenile salmonids overwintering in freshwater do not necessarily form an annulus on their scales. Jensen and Johnsen (1982) found that yearling Atlantic salmon (Salmo salar) and brown trout (S. trutta) collected in May before the emergence of fry from

the previous fall's spawning had not formed scales or lacked annuli (< 5 circuli) in years with low water temperatures (< 1000-1100 °C days from May to October). When the number of degree-days was less than 720 for 24 populations of spring spawning cutthroat (S. clarki) and rainbow-cutthroat hybrid (S. gairdneri x S. clarki) trout, no trout formed a first-year annulus, but when the degree-days exceeded 1500, all the trout formed a first-year annulus (Lentsch and Griffith 1987). Tutty and Yole (1978) indicated that some juvenile chinook salmon overwinter in upper Fraser River tributaries in British Columbia without forming an annulus. Smolts with and without an annulus (mean fork length 83 mm) as well as young-of-the-year (mean fork length 40 mm) were found in the glacial-fed McGregor River (a tributary of the upper Fraser River) and its tributaries, while all smolts (mean fork length 102 mm) from the warmer lake-fed Nechako River had formed distinct freshwater annuli in May. The degree days from mid-May to mid-October for the Nechako and McGregor Rivers were 2057 °C and 1427 °C, respectively (Anonymous 1977). Tutty and Yole (1978) postulated that the cold flows of the glacial McGregor River and other upper Fraser River tributaries may provide insufficient productivity and length of growing season to distinguish differential growth rates on the scales of juvenile chinook salmon rearing for one year.

Juvenile chinook salmon in the Yukon River also experience severe winters, late springs and short summers (Anonymous 1989). Average degree-days from mid-May to mid-October were calculated from available temperature records (Anonymous 1977) for the Yukon River at Whitehorse (1520 °C days), Takhini River (1472 °C days), Teslin River (1404 °C days), Ross River (1398 °C days), McClintock Creek (1315 °C days), Big Salmon River (1106 °C days), and Klondike River (1000 °C days). These data indicate that there are marked differences in water temperature and length of growing season among tributaries, and that the potential exists in some tributaries for slow juvenile growth. If annulus formation in juvenile chinook salmon is temperature and thus growth-dependent as has been reported for trout, then an annulus may not form on the scales of slow growing fish (i.e. fish with < 5 circuli in late August).

We found that age 1.0 juvenile chinook salmon from the upper Yukon River had very distinct annuli on their scales. Walker (1983) found that early in the spring, young-of-the-year and age 1.0 chinook salmon in the Chena River, Alaska could be separated by their distinct sizes, but as the summer progressed, the size ranges of the slow growing age 1.0 and fast growing young-of-the-year overlapped and the two age classes could not be separated by length-frequency, scale or otolith characteristics, presumably because there was no identifiable annulus present on these structures. This suggests that the juveniles that had overwintered had not formed an annulus after their first season's growth.

Juvenile chinook salmon collected in Bearfeed and Tatchun creeks in May had no discernable annulus and their large size indicated that they had overwintered. Koo (1962) found that the freshwater annulus of Alaskan sockeye salmon (O. nerka) formed between October and June, and that it was difficult to detect the annulus until widely spaced circuli were present on either side of the annulus. Juvenile chinook salmon collected in the spring may not have grown enough to produce widely spaced circuli or plus growth after the annulus, thus making annulus detection difficult. Alternatively, the freshwater annulus may not form on the scales of upper Yukon River chinook salmon until sometime after May.

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Table 1. Mean fork length (mm) of juvenile chinook salmon collected from upper Yukon River tributaries in 1987 and 1988. N is the number of juveniles collected from each tributary.

			Fork Length		Total Number of Circuli														
Stock	Date D/M/Y	Age	N	Mean (mm)	N	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Bearfeed Cr.	25/08/87	0.0	136	59	135		50	54	58	62	68	71	82	85						
	26/05/88	0.0	6	72	6			68	67					96						
	09/08/88	0.0	50	54	49	51	52	51	63	65										
Big Salmon R.	17/07/88	0.0	34	53	21	47	51	56	55											
Blind Cr.	09/08/88	0.0	42	62	41		68	67	71	70	75									
		1.0	25	83	25					66	69	72	82	89	84		87	93		

Table 1. Continued

Stock	Date D/M/Y	Age	Fork Length N	Fork Length Mean (mm)	Total Number of Circuli N	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Flat Cr.	11/08/88	0.0	75	66	71			62	63	67	72	73								
Fortymile Cr.	06/08/88	0.0	65	68	65			61	67	68	70	71	73	71						
Mayo R.	09/08/88	0.0	33	68	33				68	65	68	68	70							
		1.0	1	75	1									75						
McQuesten R.	31/08/87	0.0	101	58	100			54	57	58	60	62								
	07/08/88	0.0	80	54	76		50	52	54	60										

Table 1. Continued

Stock	Date D/M/Y	Age	Fork Length N	Fork Length Mean (mm)	Total Number of Circuli N	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nisutlin R.	23/08/87	0.0	159	59	159			54	57	60	64	67								
Nordenskiold R.	29/08/87	0.0	71	59	71				61	61	64	68	72							
	04/08/88	0.0	64	65	54		62	62	64	66	67	73	80							
Klondike R.	05/08/88	0.0	75	68	67		61	66	67	70	73	71	77	68						
		1.0	1	89	1						89									
Ross R.	09/08/88	0.0	19	64	18				65	63	66	71								

Table 1. Continued

Stock	Date D/M/Y	Age	Fork Length N	Fork Length Mean (mm)	Total Number of Circuli N	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Sydney Cr.	11/08/88	0.0	29	63	25			60	64	66	66									
Takhini R.	07/07/88	0.0	17	46	6	47	49													
	20/08/88	0.0	8	72	5			73	75		78	79								
Tatchun Cr.	30/08/87	0.0	32	67	32			66	64	66	71	78								
	26/05/88	0.0	2	69	2					69										
	04/08/88	0.0	80	63	76			62	61	63	64	67	66							
Wolf Cr.	04/07/88	0.0	8	74	8				70		69	66	74							
		1.0	6	102	6													98		106

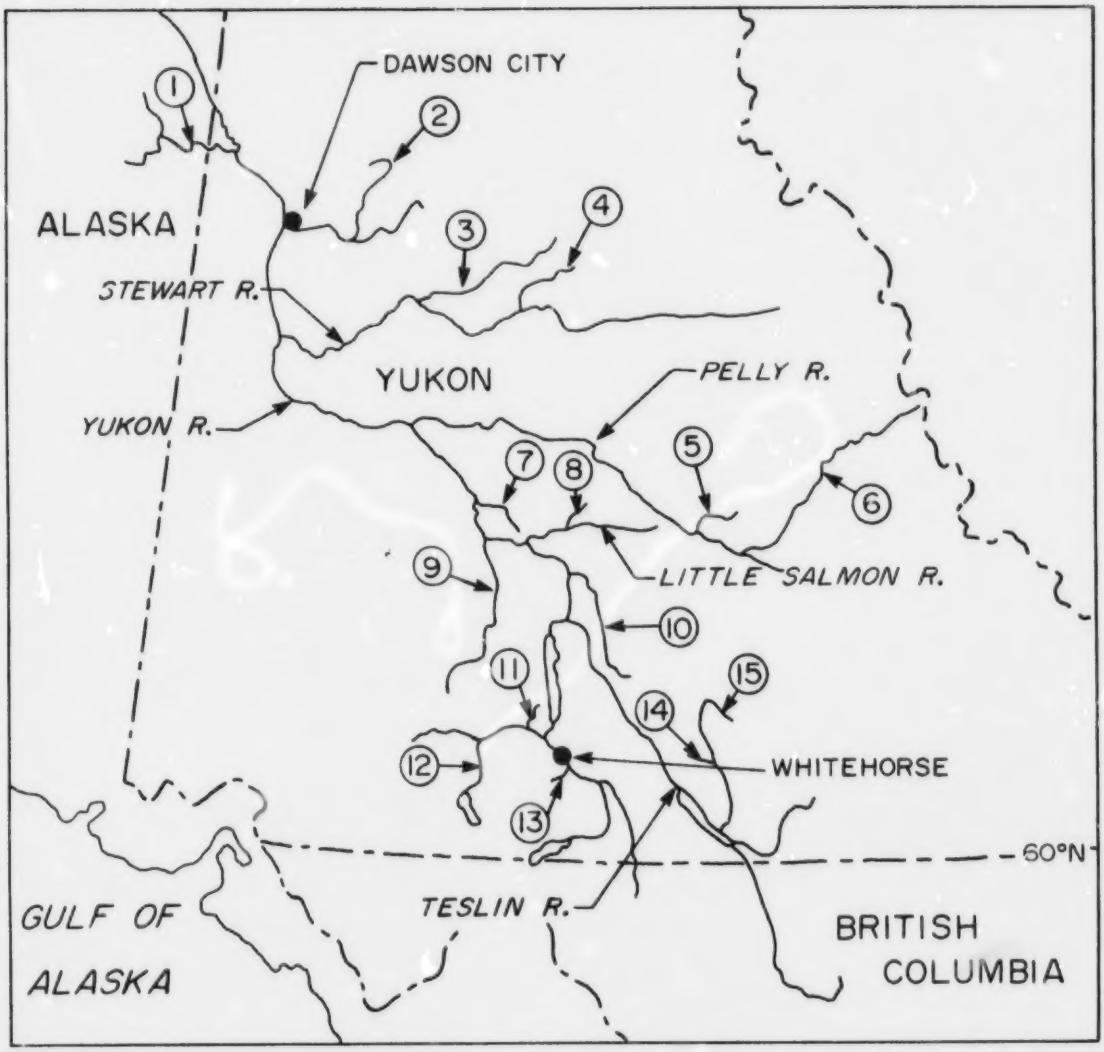

Fig. 1. Locations in the Yukon Territory where juvenile chinook salmon were sampled during 1987 and 1988, listed in ascending order: (1) Fortymile Cr., (2) Klondike R., (3) McQuesten R., (4) Mayo R., (5) Blind Cr., (6) Ross R., (7) Tatchun Cr., (8) Bearfeed Cr., (9) Nordenskiold R., (10) Big Salmon R., (11) Flat Cr., (12) Takhini R., (13) Wolf Cr., (14) Sidney Cr., and (15) Nisutlin R.

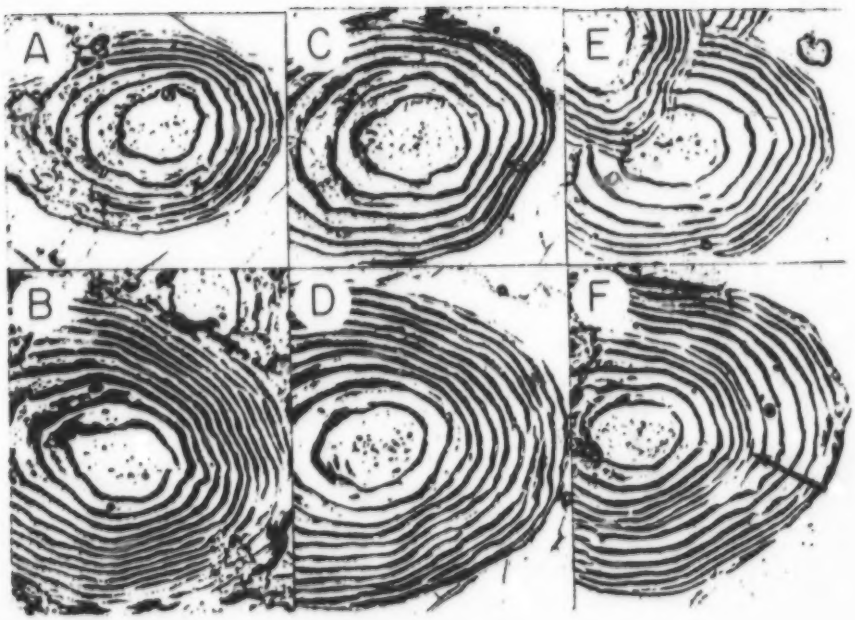

Fig. 2. Light micrographs of scales from upper Yukon River juvenile chinook salmon (magnification 100X). A) and B) from Bearfeed Creek fish collected in late May 1988, 64 and 96 mm fork length, respectively. C) and D) from Bearfeed Creek fish collected in late August 1987, 64 and 83 mm fork length, respectively. E) and F) from Blind Creek fish collected in early August 1988, 64 and 88 mm fork length, respectively. No annulus present on scales A) through E). Arrow indicates annulus on scale F).

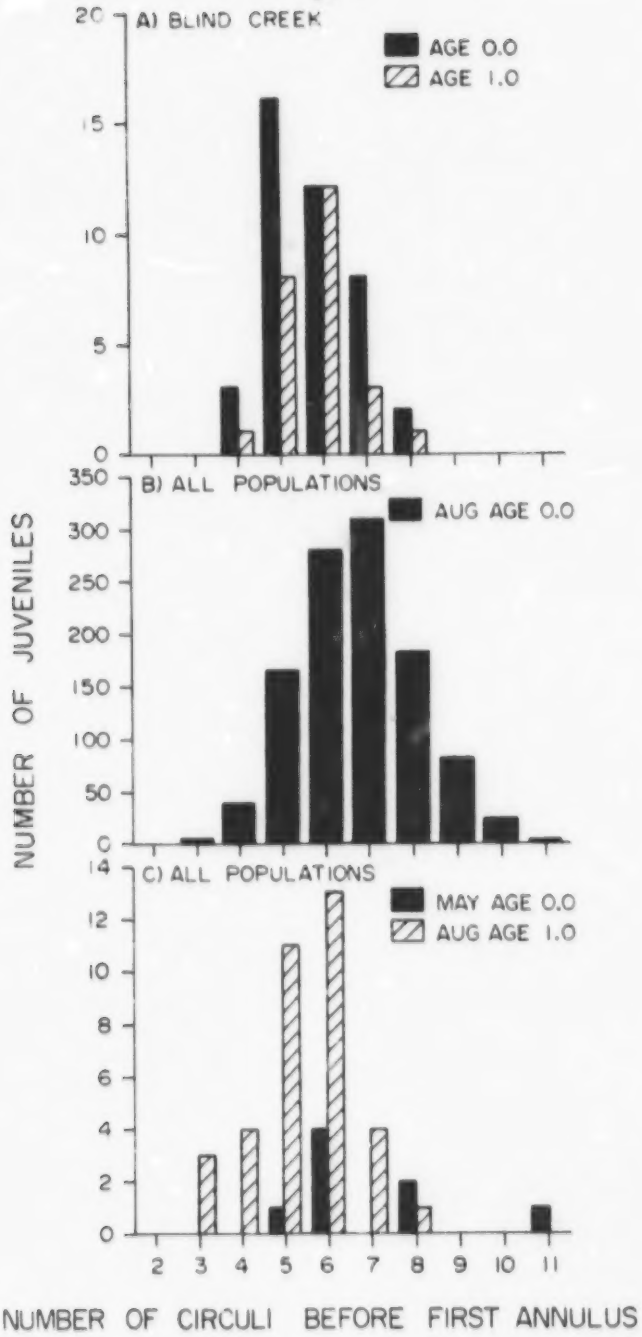

Fig. 3. Frequency histograms of circulus counts before the first annulus for: A) age 0.0 and 1.0 juvenile chinook salmon from Blind Creek in August 1988; B) age 0.0 juveniles from all upper Yukon River populations sampled in August 1987 and 1988; C) age 0.0 (assumed to be age 1.0 fish without a discernable annulus) and 1.0 juveniles from all upper Yukon River populations sampled in May and August 1988, respectively.